

University of Groningen

Controlling the optoelectronic and anti-icing properties of two-dimensional materials by functionalization

Syari'ati, Ali

DOI:

[10.33612/diss.117511370](https://doi.org/10.33612/diss.117511370)

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version

Publisher's PDF, also known as Version of record

Publication date:

2020

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):

Syari'ati, A. (2020). *Controlling the optoelectronic and anti-icing properties of two-dimensional materials by functionalization*. [Thesis fully internal (DIV), University of Groningen]. University of Groningen.
<https://doi.org/10.33612/diss.117511370>

Copyright

Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

The publication may also be distributed here under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license. More information can be found on the University of Groningen website: <https://www.rug.nl/library/open-access/self-archiving-pure/taverne-amendment>.

Take-down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Downloaded from the University of Groningen/UMCG research database (Pure): <http://www.rug.nl/research/portal>. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.

Controlling the optoelectronic and anti-icing properties of two-dimensional materials by functionalization

Ali Syari'ati

Controlling the optoelectronic and anti-icing properties of two-dimensional materials by functionalization

Ali Syari'ati
PhD Thesis
University of Groningen



university of
 groningen

faculty of science
and engineering

zernike institute for
advanced materials



lembaga pengelola dana pendidikan

The research presented in this thesis was performed in the research group of Surfaces and Thin Films of the Zernike Institute for Advanced Materials at the University of Groningen, The Netherlands. Ali Syari'ati received a PhD scholarship from Indonesia Endowment Fund for Education (LPDP), Ministry of Finance, Republic of Indonesia.

Cover design by Ali Syari'ati
Interior page layout by Ali Syari'ati
Artwork by Metta Ratana || mettadini@gmail.com
Printed by ProefschriftMaken || www.proefschriftmaken.nl

Paranymphs:
Feng Yan || f.yan@rug.nl
Dr. Oreste De Luca || o.de.luca@rug.nl

Zernike Institute PhD thesis series 2020-05
ISSN: 1570-1530
ISBN: 978-94-034-2390-6 (printed version)
ISBN: 978-94-034-2391-3 (electronic version)

© 2020, Ali Syari'ati

All rights reserved. No part of this thesis may be reproduced, stored, or transmitted in any form or by any means without the prior permission of the copyright holder, or when applicable, of the publishers of the scientific papers.



university of
groningen

Controlling the optoelectronic and anti-icing properties of two-dimensional materials by functionalization

PhD thesis

to obtain the degree of PhD at the
University of Groningen
on the authority of the
Rector Magnificus Prof. C. Wijmenga
and in accordance with
the decision by the College of Deans.

This thesis will be defended in public on

Friday 21 February 2020 at 14.30 hours

by

Ali Syari'ati

born on 21 April 1990
in Cirebon, Indonesia

Supervisor

Prof. P. Rudolf

Co-supervisor

Prof. M. A. Stöhr

Assessment Committee

Prof. P. Reinke

Prof. M. A. Loi

Prof. R. M. Hildner

For my parents, my wife and my daughter!

Untuk Ibu, Ayah, Liany dan Naureen!

Table of Contents

Chapter 1

General Introduction	1
1.1 Motivation	2
1.2 Graphene	3
1.3 Transition Metal Dichalcogenides	6
1.4 Molybdenum disulfide (MoS ₂).....	7
1.4.1 Crystal Structure	7
1.4.2 Electronic and Optical Properties	9
1.4.3 Defects and defect engineering in MoS ₂	10
1.5 Outline of Thesis.....	16
References	19

Chapter 2

Experimental Details	23
2.1 Synthesis Method.....	24
2.1.1 Chemical Vapor Deposition.....	24
2.2 Characterization Techniques	26
2.2.1 X-ray Photoelectron Spectroscopy	26
2.2.2 Raman Spectroscopy.....	32
2.2.3 Fourier-transform Infrared Spectroscopy	34
2.2.4 Photoluminescence Spectroscopy	35
2.2.5 Atomic Force Microscopy	36
2.2.6 Scanning Electron Microscopy	37
2.2.7 Transmission Electron Microscopy.....	38
2.2.8 Contact angle measurement	40
2.2.9 X-ray Diffraction.....	41

2.2.10 Transport measurements.....	42
References	46

Chapter 3

Controlling the MoO₃ precursor provision to obtain high quality single layer MoS₂ by chemical vapour deposition	49
3.1 Introduction.....	50
3.2 Results and discussion.....	52
3.3 Conclusion	62
References	63

Chapter 4

Photoemission Spectroscopy Study of Structural Defects in Molybdenum disulfide (MoS₂) Grown by Chemical Vapour Deposition (CVD).....	67
4.1 Introduction.....	68
4.2 Results and discussion.....	69
4.3 Conclusion	78
References	79

Chapter 5

Enhancing the photoluminescence efficiency of CVD grown MoS₂ via defect engineering	83
5.1 Introduction.....	84
5.2 Results and discussion.....	86
5.3 Conclusion	95
References	96

Chapter 6

Up-scalable production of an anti-icing coating based on graphene oxide

.....	99
6.1 Introduction.....	100
6.2 Results and discussion.....	101
6.2.1 Characterizations of graphene oxide.....	102
6.2.2 Graphene oxide deposition by the Langmuir-Schaefer method.....	105
6.2.3 Characterizations of graphene oxide on oxidized silicon.....	106
6.2.4 Ice formation on bare and GO-covered oxidized silicon.....	107
6.3 Conclusion.....	110
References	111
 Summary	 113
Samenvatting	117
Acknowledgements	121
List of publications	129
The Author	131

